along the immediate coast at low elevations; however, as shown by Petterssen, in several cases the low ceiling was due to a double inversion that produced fog in the morning some time after insolation had destroyed the small lower inversion.

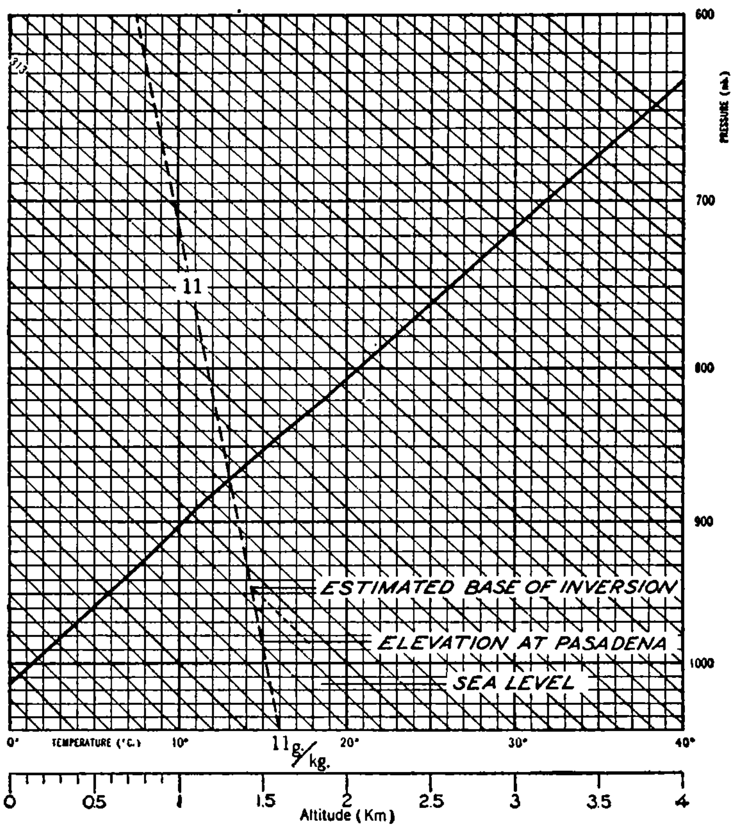

FIGURE 2.—Diagram showing method employed to calculate the temperature necessary to produce fog at Pasadena on the evening of July 18, 1937. The solid diagonal line is a pressure-height curve to be used in conjunction with the lower horizontal scale for determining altitude

An example of a double inversion at Pasadena occurred on the morning of July 19, 1937. When the forecast was made the previous evening, the base of the inversion was estimated to be about 600 meters, as determined from the morning aerographic observations. The surface-mixing ratio at Pasadena was calculated to be about 11g/kg. From an altitude of 600 meters (see figure 2) on the 11g/kg curve of mixing ratio, projecting down along the dry adiabat to the surface elevation of Pasadena a temperature of 17.8° C. was found necessary to produce fog. The minimum temperature for the next morning was expected to be several degrees lower than that; therefore fog was expected to form.

At 7:50 p. m., July 18, the airway reports indicated temperatures from 17.9° to 18.4° C. and mixing ratios of about 11g/kg on the coast. Projecting the surface sea level temperature upward along the dry adiabat to the 11 curve of constant saturation mixing ratio would indicate a convective condensation level between 300 and 350 meters. Yet no fog was reported overhead by any of the stations, which would indicate that the base of the inversion was below 300 meters. Some of the stations reported low fog banks seaward, which would also indicate the base of the inversion to be very low. Since there was no justification for such a low base for the inversion, as shown by the synoptic situation, the only conclusion to be drawn was that a double inversion existed in the air. This proved to be true because by 4:50 a. m., July 19, fog was reported all along the coast, with ceilings ranging from 150 meters to 240 meters. No fog had occurred at Pasadena or Burbank up to this time. At 6:30 a. m., 1 hour and 45 minutes after sunrise, when the lower inversion was destroyed, fog formed at Pasadena and continued until about 7:45 a. m. Burbank reported dense fog at 6:50 a. m.; and the ceiling at San Diego had risen to about 400 meters.

A plotting board was constructed to aid in making quick analyses for fog forecasting: On one side a Millar nomogram [4] is mounted under celluloid for determining the surface mixing ratio. On the other side a pseudo-adiabatic diagram was mounted to be used in determining the temperature necessary to produce fog.

The method of fog forecasting presented in this article is considered to be reliable whenever the height of the base of the inversion can be closely determined, and when a fall in temperature below that necessary to produce fog is predictable. In the short period of 4 months' trial at Pasadena it has been highly successful.

[4] Rapid Methods Of Calculating The Rossby Diagram, F. Graham Millar, Bulletin of the American Meteorological Society, October 1935, pp. 229-233.

SYNOPTIC ANALYSIS OF THE SOUTHERN CALIFORNIA FLOOD OF MARCH 2, 1938

By CHARLES H. PIERCE

[Weather Bureau, Washington, June 1938]

On the morning of March 1, a deep LOW with a wide-open warm sector was centered at latitude 34° N., about half way between San Francisco and the Hawaiian Islands.

The warm front of this LOW was peculiar because instead of extending southward, as do most warm fronts of the Pacific LOWS in this locality, it extended east-southeastward and was connected to a cold front of a preceding system which had passed inland on the previous day. This cold front extended through southern California and passed into Mexico during the day, giving California temporary clearing that afternoon.

In the meantime, the LOW which was centered at 34° N. and 140° W. was occluding and moving rapidly northeastward, being centered at approximately 39° N. and 132° W. at 4:30 p. m. (all times Pacific Standard). In spite of the rapid occlusion near the center, there was still a very extensive warm sector with a supply of moist Tropical Pacific air a short distance southwest of southern California. With the LOW moving so rapidly northeastward, it meant that the cold front that had passed southward of the international boundary would soon change its direction of motion, and start returning as a warm front.

Late that night rain was already falling along the coast from the overrunning warm air to the southwest.

At 4:41 a. m. March 2, the low center was off the Oregon coast with an occluded front, north of Marshfield and Roseburg, Oreg., which curved sharply southwestward into California. The position of the fronts and the pressure distribution over California at 4:41 a. m. is shown by the map of that time for March 2.

In the following 6 hours the cold and occluded fronts advanced rapidly eastward with the warm front moving with equal speed to the northeast. The position of the fronts and pressure field at 10:41 a. m. is shown on the map.

The warm-front passage was not noticeably marked along the coast and in the valley stations, although in most cases the wind shifted from southeast force 4 Beaufort, to south or south-southwest force 5 Beaufort, accompanied by a temperature and dew-point rise of 3° to 6°. Burbank, for instance, shifted from southeast 15 miles per hour to south 13 miles per hour with temperature and dew point rising from 56°/56° to 61°/61° within 35 minutes from 8:41 a. m. to 9:15 a. m. The front passage was more marked at the higher stations. Sandberg shifted from south 26 to south-southwest 48 with temperature and dew point increasing from 45°/45° to 48°/48° at 10:41 a. m. and to 50°/50° within the next hour. Palmdale shifted from north 8 to west-southwest 43 with the temperature and dew point jumping up from 50°/50° to 58°/55°. It may have been that some of the cold air was trapped on the southern slope of the mountains, but it seems likely that this air was mixed with the TP air under the strong turbulent conditions that prevailed throughout this area.

One of the most interesting features of the storm was the rainfall pattern before and after the passage of the warm front. Table 1 shows the hourly rainfall for seven stations in the Los Angeles area. Los Angeles, Van Nuys, and Claremont are valley stations, while the others are located along the slope of the Sierra Madre Range and are termed mountain stations. The location and the elevations of these stations are shown in figure 1.

It will be noted that during the hours before the warm-front passage in the early morning, the rainfall for all stations was about equal with an hourly rate between .30 and .75 of an inch. After the warm front had passed to the north of the Sierra Madres, there was a noticeable increase in the hourly rate for the mountain stations with continuous heavy precipitation amounting to over 1.00 inch per hour in most cases. On the other hand, the rainfall at the valley stations did not increase at all, but showed a shower type of precipitation that one would expect in the conditionally unstable tropical maritime air. The hourly rates at Los Angeles seen in the table from 10:00 a. m. to 4:00 p. m. indicate this.

The heavy rainfall for the mountain stations may be explained by the more rapid lifting of the TP air against the southern slope of the mountain. As Daingerfield states in his paper on this storm, the Sierra Madres acted as a permanent front to the air in the warm sector. However, the front caused by this mountain range was much steeper than the normal warm front between two air masses. The rough cross section through Los Angeles and Palmdale, figure 2, indicates the difference in stream lines of the tropical air before and after the front passage. At 4:41 a. m. all the stations were within the cold air, and the TP air was being lifted along the front at the same rate over all the stations. Six hours later, after the front had passed, the air flow was such that the lifting of the TP air was very pronounced on the southern side of the ranges, resulting in the heavy rain on these slopes.

The frontal motions decelerated late in the morning and during the afternoon. The cold front passed Bakersfield before 11:41 a. m. with the temperature dropping 7° and a shift of wind from Southwest to Northwest. Sandberg showed a very decided front passage about 1:41 p. m. The passage of the front in the valley stations was masked by the topography as usual, although there was a diminishing of the wind velocity and a slight shift of wind to a westerly component. Also the temperature and dew-point dropped 3 to 5 degrees.

There was no marked increase in the rainfall with the cold-front passage, although it was accompanied by a shower about equal to the heaviest hourly rainfall of the storm for the particular station. The reason that the rainfall was not any heavier at the time of the cold-front passage, in the mountains anyway, was because it probably did not offer any additional lift to the tropical air. The passage of the front was marked by the eastward progress of the final shower, as will be seen upon the study of table 1. Following the passage of the front, the rainfall became light even at the mountain stations, and by 5:41 p. m., Burbank and Palmdale reported breaks in the clouds. The location of the fronts and the pressure field at 3:41 p. m. and 4:41 p. m., is shown on the maps. The hourly positions of the cold front from 2:41 p. m. to 5:41 p. m., inclusive, is shown also in figure 1.

In review then, the synoptic causes of the record breaking rainfall for southern California during the storm of March 2, 1938, were mainly the following three: (1) There was a good supply of moist Tropical Pacific air over a large area of the ocean southwest of the southern coast. This had been transported into this region by several waves moving across southern California prior to March 2. (2) The storm of March 2 had a circulation and a frontal set up such that excessive rains could be produced. (3) The orographic effect produced rapid lifting of the warm moist air.

In the first place the storm had a steep pressure gradient which rapidly transported Tropical Pacific air northeastward from an extensive warm sector. This air moved almost normally to a steep warm front surface which produced in the neighborhood of 3 to 5 inches of warm-front rains at the hourly recording stations.

After the warm-front passage, convergence within the airmass caused by the rapid transport of air into the low-pressure area and convergence caused by deepening of the LOW in this area produced unstable conditions of the air which would have probably caused heavy showers even over flat country. However, orographic conditions in the form of the Sierra Madre Range directly across the path of this rapidly-moving conditionally-unstable air was the main factor in the excessive rains. Then added to this, the stream of Tropical Pacific air prevailed unabated for 6 hours across this region before it was cut off by the passage of the cold front.

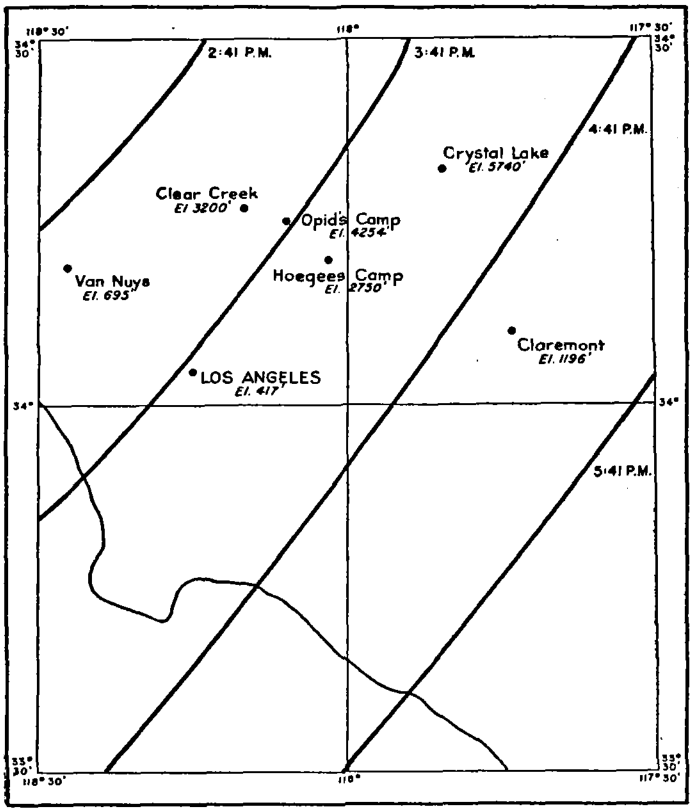

FIGURE 1.—Map showing hourly progression of cold front from 2:41 to 5:41 p. m., March 2, 1938, in relation to location of recording rainfall stations in Los Angeles area.

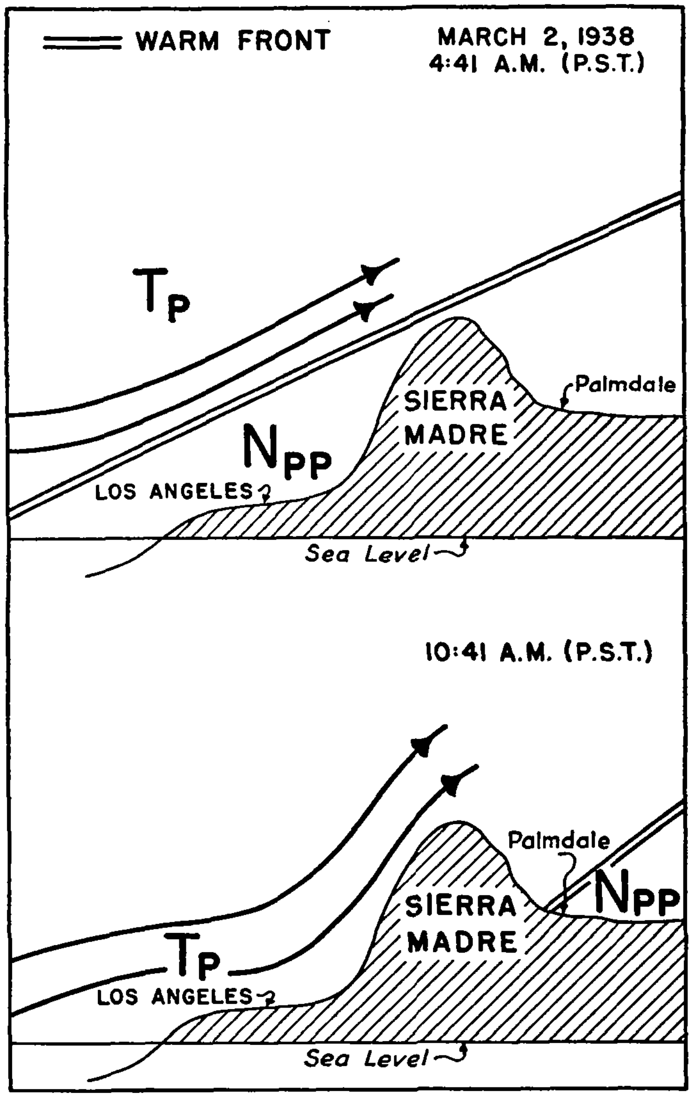

FIGURE 2.—Cross section extending through Los Angeles and Palmdale, Calif., showing streamline flow of Tp air before and after the warm front passage.

TABLE 1.—*Hourly precipitation amounts, 9 p. m., March 1, to midnight, March 2, inclusive*

Station	March 1				March 2												March 2												Total
	P. M.				A. M.												P. M.												
	9	10	11	Midnight	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Midnight	
Claremont, No. 92	----	----	----	0.10	0.21	0.10	0.10	0.17	0.29	0.45	0.45	0.58	0.43	0.39	0.17	0.23	0.23	0.50	0.40	0.24	0.22	0.44	0.09	----	0.01	----	0.01	------	5.81
Clear Creek, No. 47A	----	----	0.10	.25	.22	.08	.15	.35	.37	.38	.41	.75	.88	1.50	1.00	1.40	1.40	1.35	1.20	.94	.55	.20	.23	0.13	.06	0.08	.05	0.08	14.11
Crystal Lake, No. 283A (East Pine Flat)	----	----	.03	.15	.24	.12	.21	.23	.33	.46	.35	.72	.79	.76	1.07	.87	1.48	1.57	1.50	(1)	2.27	.36	.11	.17	.31	.07	.18	.14	14.49
Hoegees Camp, No. 60A	----	0.01	.13	.33	.15	.22	.36	.42	.59	.49	.72	.53	1.17	1.20	.82	.95	1.29	1.11	1.31	1.47	.79	.20	.08	.27	.01	.11	.05	.06	14.84
Los Angeles	T	.01	.15	.24	.10	.07	.14	.44	.68	.34	.77	.54	.59	.45	.02	.33	.08	.41	.19	.42	.20	.08	T	.03	----	----	----	------	6.28
Opids Camp, No. 57 [2]	----	.01	.13	.27	.13	.24	.39	.40	.56	.41	.75	.54	.96	1.67	.92	1.09	1.37	1.45	.38	1.42	.90	.21	.07	.19	.12	.07	.12	.09	14.86
Van Nuys, No. 15	----	.02	.10	.20	.08	.08	.24	.38	.39	.38	.39	.32	.44	.29	.19	.60	.48	.38	.39	.14	.10	.06	----	.03	----	----	----	------	5.68

[1] Included in next hour. Gage at capacity during interval. Standard gage reading used.
[2] Automatic gage reached capacity at 2:18 p. m. Interpolation made from intensity gage readings for the remaining hours.

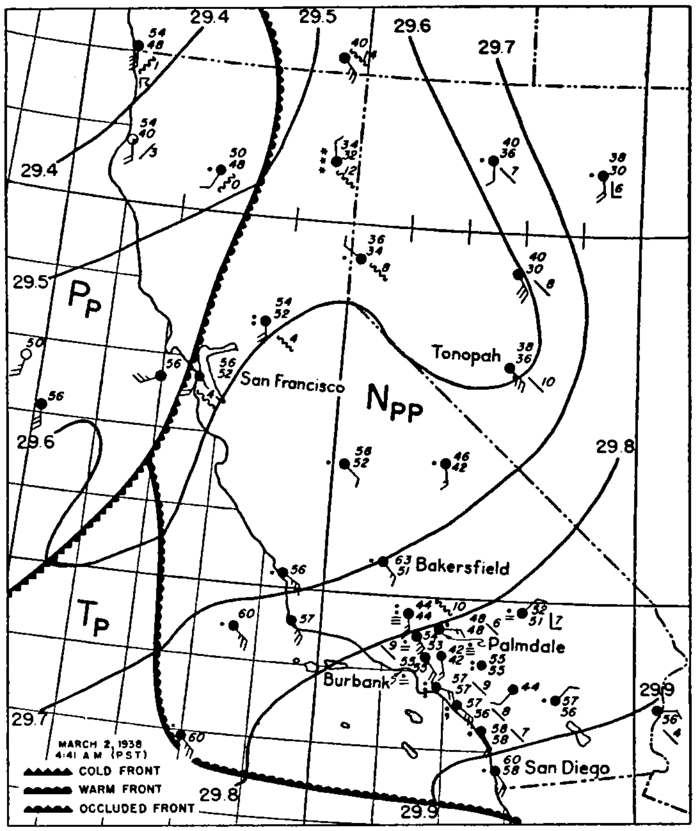

FIGURE 3.

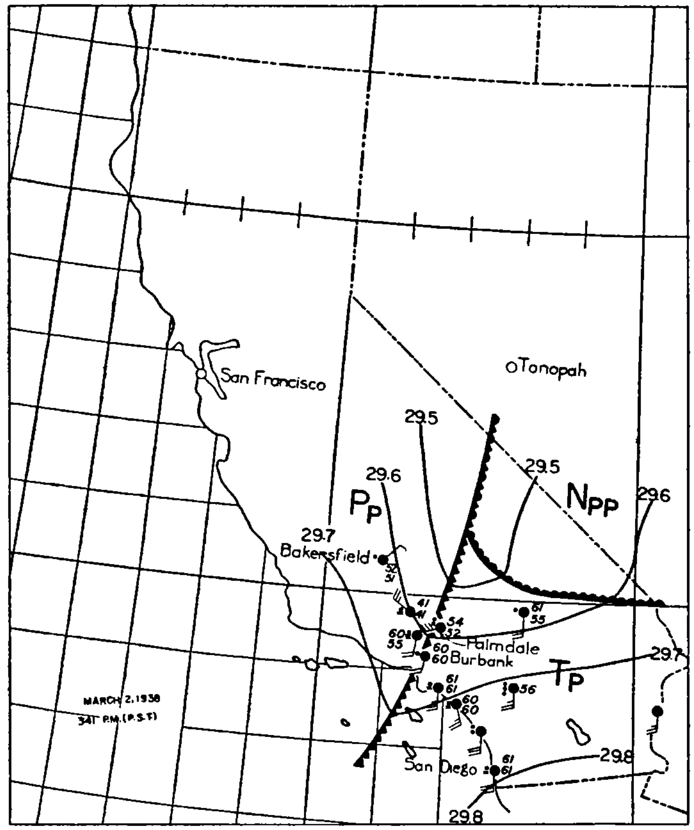

FIGURE 5.

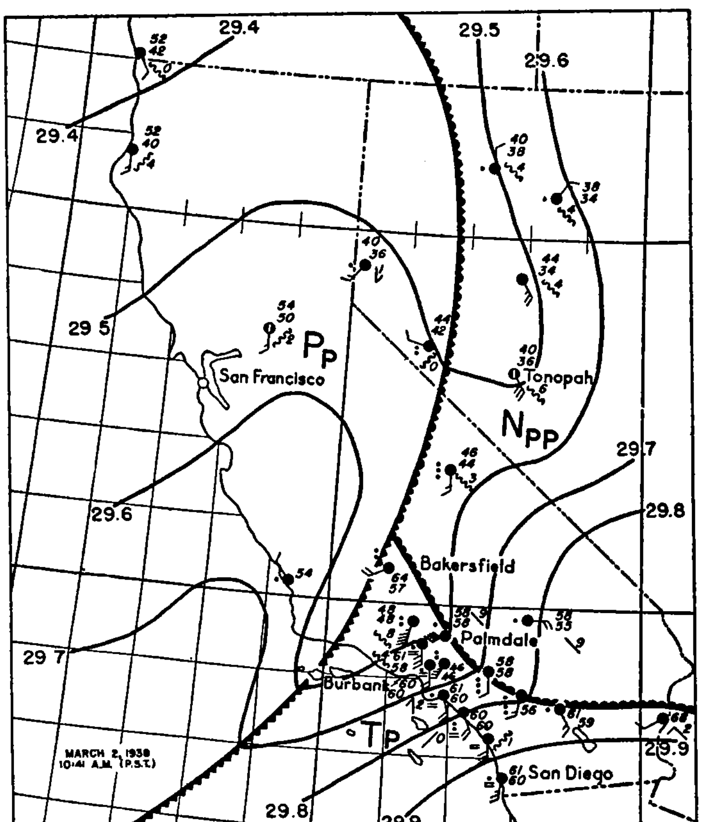

FIGURE 4.

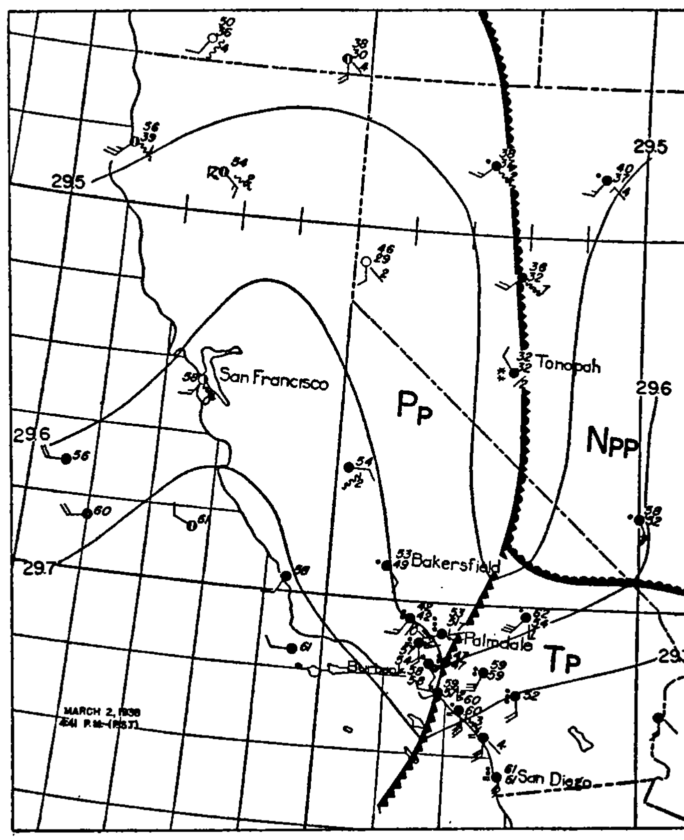

FIGURE 6.